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Merging BIM and GIS using ontologies application to urban facility management in ACTIVe3D

Clement Mignard [a,b,*], Christophe Nicolle [a]

[a] LE2I, UMR CNRS 6306, Faculté des Sciences Mirande, BP 47870, University of Bourgogne, 21078 Dijon Cedex, France
[b] ACTIVe3D, 2 rue René Char, BP 66606, 21066 Dijon Cedex, France

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ABSTRACT

This article presents the research work done in order to reduce the gap of heterogeneity between Geographic Information System and Building Information Models. The goal is to extend a platform dedicated to facility management called ACTIVe3D. We want to enlarge its scope to take into account the management of urban elements contained in the building environment, as well as other buildings. The particularity of the platform is that data can be accessed either by a semantic view or through a 3D interface. The SIGA3D project describes a set of processes that aims, for all the stakeholders of urban projects, to manage pieces of information through all the lifecycle of construction projects. To solve the heterogeneity problem between BIM and GIS, we developed a semantic extension to the BIM called UIM (Urban Information Modeling). This extension defines spatial, temporal and multi-representation concepts to build an extensible ontology. The knowledge database can be populated with information coming from standards like IFC and CityGML. This information system has been adapted and implemented into the existing platform and is today fully operational and used by thousands of users.

1. Introduction

From its design to its construction, a building requires coordination, understanding and a chain of numerous heterogeneous systems for every stakeholder involved in the project. The fields of construction and CAD (Computer Aided Design) had to adapt themselves over these past years to gain efficiency. An open standard has been proposed to model buildings. This standard is known as IFC (Industry Foundation Classes). From there, a discipline entitled BIM (Building Information Modeling) emerged. It consists in generating, storing, managing, exchanging and sharing building information in an interoperable and reusable way throughout all the lifecycle of a building.

BIM consists in treating the building as a fully-fledged information system. Even if the term BIM has existed for many years, today's meaning was democratized in the mid-2000s. Since then, more and more building stakeholders (architects, engineers, contractors, etc.) have chosen to use BIM for their activity [11]. The first semantic-oriented BIM solutions have emerged recently. The semantic BIM consists in modeling buildings with ontologies to obtain easily graphs easy to handle. Such BIM are based mainly on the IFC standard (ISO 16739:2013) as described in the works of Benner et al. and Vanlande et al. [4,19]. Today, perfectly operational and accomplished solutions are used in many countries by various legal entities (governments, administrations, private companies, etc.).

IFC is a standard created by an association known today as BuildingSmart.[1] The IFC file format aims to provide a structured and shared view of the objects that makes up the building. Several studies have been made over the past decade to build ontology from such a format, such as those of Benner et al. and Vanlande et al. [4,19]. The semantic modeling of the building brings many benefits, such as interoperability between different applications and the ability to contextualize the data in order to create specific views for specific core businesses.

This is the case, for example, of the ACTIVe3D platform (A3D) which is developed since 2005 [19]. This platform is currently used in France by several universities (Nice), regions (Burgundy), cities (Paris), and ministries (Defense). All data managed with ACTIVe3D

* Corresponding author at: Faculté des Sciences Mirande, BP 47870, University of Burgundy, 21078 Dijon Cedx, France. Tel.: +33 380396857.
E-mail addresses: clement.mignard@gmail.com (C. Mignard), cnicolle@u-bourgogne.fr (C. Nicolle).

[1] http://www.buildingsmart.org/.

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today represents over 100 M square meters with several tools dedicated to facility management.

However, if BIM has been developed in recent years, its needs and features also have. We can take the example of the regions in France. They have since recently to manage the waterways. These canals often extend over several hundred kilometers. To manage them effectively, we need to represent all bays, locks, houses, trees, benches and other comprising elements both geometrically and semantically. This model will then be used in expert facility management software to anticipate the inherent costs needed to maintain them. BIM quickly found its limits on this type of project for many reasons: accuracy in locating objects on large sites, linking different complex objects, information about the surrounding landscape, spatial queries, etc.

The BIM approach on which we rely must then be extended with GIS (Geographic Information System) mechanism. The use of GIS to manage facilities is not a solution since GIS has a limited management of semantic information on the components from the different layers of the information system. Indeed, GIS are designed to deal mainly with large scale and the needs of facility management remains strong at the building scale. We therefore wish to couple BIM and GIS approaches to standardize the representation of knowledge related to the building and geographic objects.

Thus, in our approach named SIGA3D, BIM is no longer limited to the description of a building, but also of the interactions with its environment. The modeling of this set is an emerging discipline that has been called Urban Facility Management (UFM) [13]. It describes a set of business processes revolving around construction and urban management. The heart of this system is based on the modeling of the urban information system, called Urban Information Model (UIM).

For this, we studied the approach made in GIS (geographic space management in the broadest sense of the term), and in particular in the urban modeling industry. According to M. Batty [2], graphical representations of functions and processes to generate urban spatial structures in terms of land use, population, employment and transport can be described as urban models. There are many heterogeneous file formats for representing geographic information. Associations and consortia such as the OGC (Open Geospatial Consortium[2]) and OSGeo (The Open Source Geospatial Foundation[3]) were created to standardize this domain. Thus, the development of new open and independent standards allows modeling geographic information. We may cite for example GML (Geography Markup Language) that describes geographic elements. GML is used for exchanging geographic information over the Internet. In particular there is a system based on GML which enriches the semantic dimension of the representation of cities, the CityGML format. As the IFC, this format allows to create knowledge databases according to the objects and relationships described in this format.

The idea of our research is to bring GIS and BIM closer by bridging the gap of heterogeneity between the two approaches. The identified kinds of heterogeneity are structural and semantic. The objective is to develop a platform for urban facility management that allows the emergence of new business disciplines by coupling these two fields of activity in a common environment. The goal is to manage urban facilities (including buildings and urban proxy elements) in an interoperable way. To achieve this, we use semantic graphs and ontologies defining concepts and relations to model all the required information. This article focuses on the semantic modeling of urban objects and describes the mechanisms set up to reach this goal.

[2] www.opengeospatial.org.
[3] http://www.osgeo.org.

Section 1 of this document is a brief state of art on the modeling of building information on the one hand, and urban information on the other hand. They are both axed on the semantic modeling approach. In the second section we discuss the limits of the urban model for the representation of building information and vice versa, the limits of BIM to manage urban and environmental information. The third section presents our semantic indexation method used to define a global ontology. This ontology is used to merge all data during the building lifecycle and its environment in order to create an urban information model. Section 4 presents the extension of the ACTIVe3D platform and the particular implementation of the SIGA3D ontology. The last section concludes this paper.

2. BIM and GIS

In this section, we present the work done in the BIM domain and especially the semantic BIM as designed in ACTIVe3D. Then we present the limits for the intended purpose. Urban modeling and GIS are then introduced.

2.1. From BIM to semantic BIM

In the paper of Vanlande and Nicolle [18], BIM is described as an intelligent representation of the building, made from CAD data, CAD objects, and parametric building modeling. The quality of the information strongly depends on the person who is inputting the data and the software used. Consequently, the models for data exchange and sharing are another main characteristic of BIM. There are several ways to share information, either in a centralized manner (database, web services, etc.), or by exchanging files by common services (e-mail, CD, USB flash drive, etc.).

The particularity of the semantic BIM is the use of ontologies to manage models. Ontologies unify the knowledge generated during each step of the building's lifecycle. For this purpose, the users describe real-world elements and their interactions with each other in the model. This is done on two levels: syntactic and structural. Users do not interact directly with the ontologies, they used CAD software that allow to design buildings in an object manner (that is to say users do not draw lines to represent a wall, but instantiate an object "wall" and its interactions with other objects). The ontology graph is then deduced from the user model.

The management of the building's lifecycle requires another management level. Indeed, the problem is that the elements and their interactions with the real-world are not the only things to model. Indeed, all the elements, their states and their interactions have to be validated. This means that, during the design time, the system retains more relevant information about the elements; the management system of the building lifecycle has to describe the components of a building project. These components are, for example, all the tangible elements (such as walls, stakeholders, and furniture), as well as immaterial elements (costs, projects, phases, actions, etc.). Moreover, the interactions between elements are modeled by links. For instance, when a wall which contains a window is moved, the window moves as well. Therefore, a wall and a window are connected by a containment relationship.

The ACTIVe3D BIM was built as an extension for the IFC model building lifecycle. This approach allows the characterization of objects that make up a building such as their classes, relations and properties throughout the entire building lifecycle and from diverse points of view [10]. The IFC standard uses files that are made of objects and connections between these objects. Attributes can be defined for objects, describing its "business semantic". The "relation elements" represent the connections between objects. The IFC model is an object model which uses the EXPRESS language (ISO standard 10303-P11, 1994). It describes more than 750 classes